SPAWAR
Systems Center
San Diego

NETWARS-NSS Federation

SPAWAR Systems Center San Diego (SSCSD)

Network Centric Warfare Analysis Branch

Outline

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- Background
- Sample Studies
- The Federation

Background

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Who We Are

- **Communication Department: Network Centric Warfare Analysis Branch**
- **Represent Navy Modeling and Simulation Management Office (NAVMSMO), OPNAV N61-M, and N61F, for Joint C4ISR Communications M&S assessment domain**
- **Supporting C4ISR Network M&S for 10 years**
- **Lead Navy NETWARS developers and support OPNAV N81 assessments with our Federation M&S environment**

What We Do

- **Perform C4ISR network/communication performance analysis**
- **Develop M&S analysis domains to support Simulation Based Acquisition**
- **Support DARPA/IPTO on transition to DoD**
- **High Performance Computing Modernization Program Office (HPCMO) in developing a M&S environment for the Navy to perform Large Scale High Fidelity Simulation**

Why M&S?

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- **Capacity Planning/Scalability**
  - Where are my network bottlenecks? Will network support future growth
- **Impact of Technology**
  - How will my new application impact existing systems?
- **Acquisition**
  - Justify the purchase of a new capability for my network.
- **Prototype development and assessment**
  - Assess and fine tune a new protocol before prototype manufacturing.
- **Training**
  - Train a Link 16 user within a virtual environment – less costly.
- **Co-simulation**
  - Link to C2 and ISR simulators for complete C4ISR assessments.

M&S Experimentation Benefits

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- Flexibility
  - what happens if I change this with that?
- Analytical rigor
  - mathematically show that derived solutions are correct
- Scalability
  - Start with simple networks, and scale up, showing how systems respond as they grow in size/traffic
- Future technologies
  - How do new technologies impact the mission?
- Inexpensive
  - M&S is MUCH cheaper that developing actual hardware and it can locate potential problems well before systems are deployed and allow time for corrections before deployment

Recent Evaluations Conducted

- Time Critical Strike -2002
- FORCENET LOE - 2003
- BattleForce Composite Networking - 2003

Modeling and Simulation Tools

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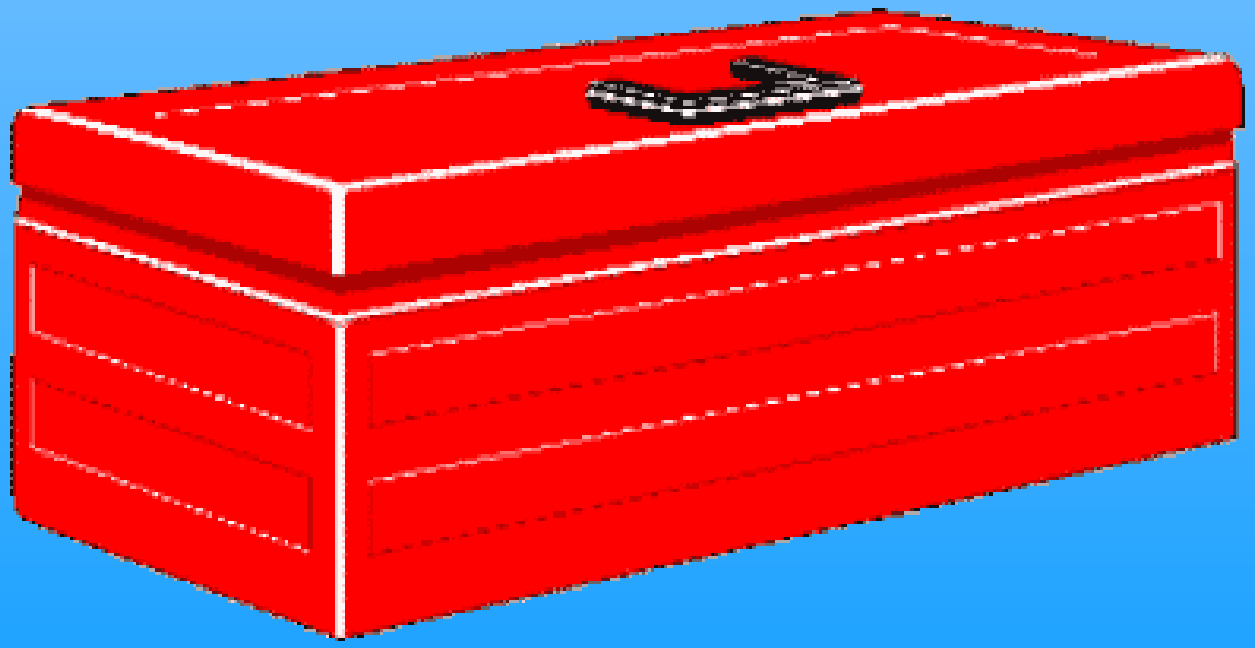

SSCSD M&S Capabilities and Resources

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- **Simulation Tools**
  - Naval Simulation System (NSS)
  - NETWARS/OPNET
  - QUALNET
  - GTI-Net
  - MAYA
- **Existing Communications Model Library**
  - COTS and GOTS protocols, devices and systems.
  - OPNAV N60M C4ISR standard models
- **Scenario and Traffic Data models**
  - Navy Defense Reference Model (DRM)
    - Operational scenarios validated by Office of Naval Intelligence
  - Probe and Information Exchange Requirements (IER) data.
    - Import real probe traffic data into modeled networks.

OPNET

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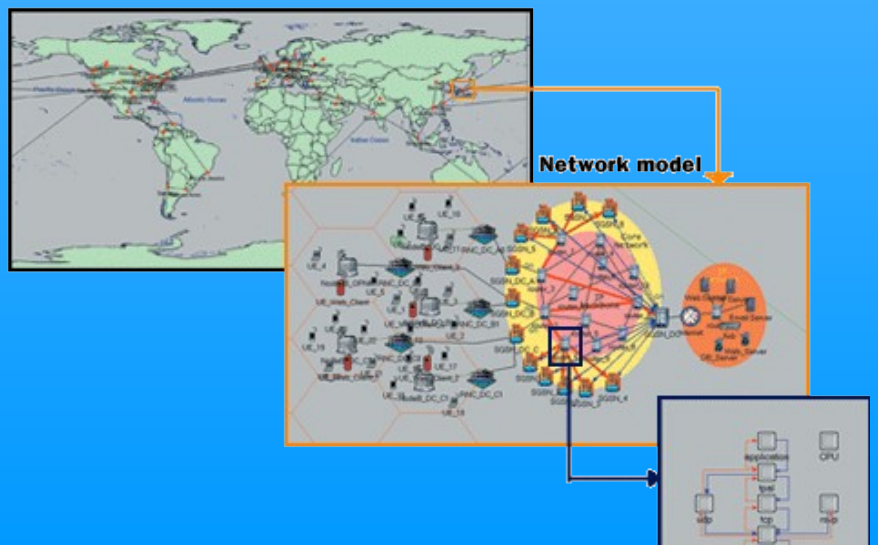
Description:

- COTS network M&S Tool
- Supports all network types
- Wireless support
- Allows development of custom protocols and devices
- Hierarchical

Relevance:

- Large number of standard devices
- Industry standard
- Supports development of military comms systems



Benefits:

- Allows for graphical display of network and results
- Accurate simulations
- Building block for

NETWARS

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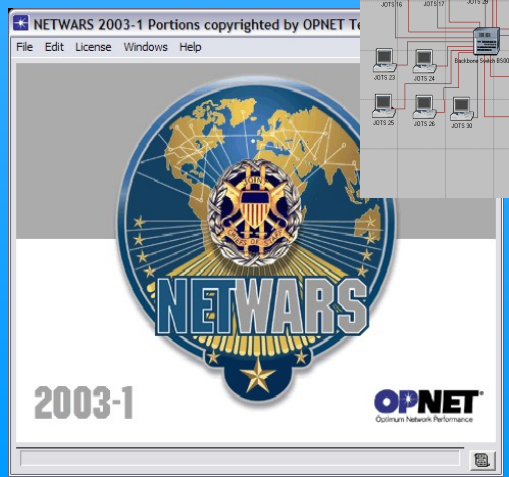
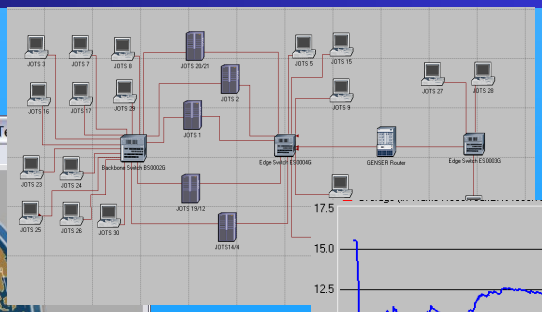
Description:

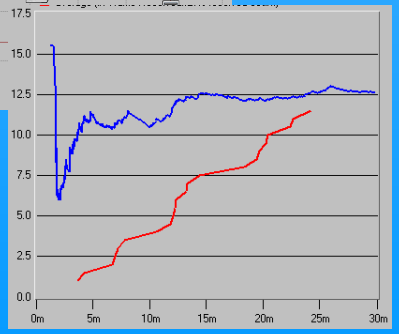
- Convert Navy Communication Models to NETWARS standards
- Create new comm models to simulate current and future systems
- Conduct Studies to support FORCEnet

Operational Relevance:

- Accurate Navy comm models required for correct joint simulations
- Analyze new comm systems before deployment







Benefits:

- Provides accurate, fast network simulations for joint task force

NETWARS

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- Simulation Tool endorsed by the Military Communications Engineering Board (MCEB) as the Joint Services communications modeling tool of choice.

- Provides a common, validated simulation capability.
  - User interfaces, Joint model architecture, and device, protocol, and traffic model libraries.
- Designed to extend M&S capability to the C/S/A's.
  - Conduct communications burden analysis at the JTF level (and below).
  - Perform rapid capacity planning
  - Evaluate impact of emerging technologies on battlefield communications
- Constructed using the Optimized Network Engineering Toolkit (OPNET)

General MS&A Approach

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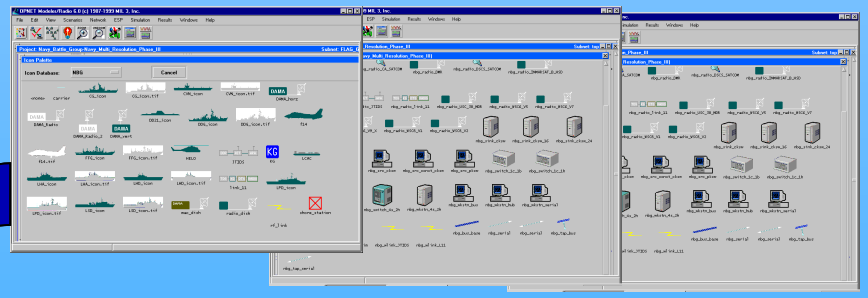
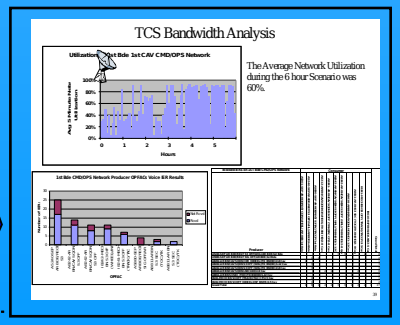
- Define MOE/MOPs
- Identify relevant organizations, protocols, and architectures.
- Define IERs
  Develop Models
- Define scenario
- Run-time
- Execute Simulation

VV&A





Measures of Performance

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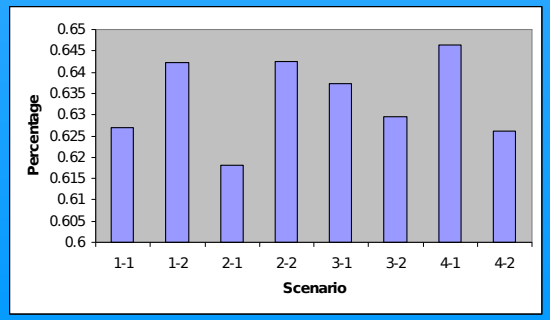
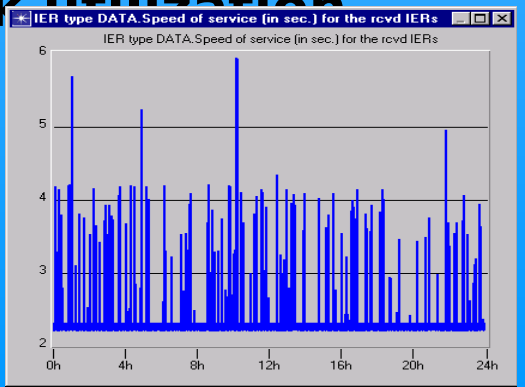
- **All Networks**
  - Total Traffic Sent
  - Total Traffic Received
  - Link Throughput
  - Link Utilization
  - Voice/Data End-to-end delay
- **Voice Networks**
  - Call Completion Rate
  - Call Blocking Probability
- **Custom MOPS**
  - e.g. Link 11 cycle time
  - e.g. TCP window size
- **Data Networks**
  - Speed of Service
  - Grade of Service
  - Connection Latency
  - Message Error Rate
- **Broadcast Networks**
  - Network utilization





Navy IER Flows

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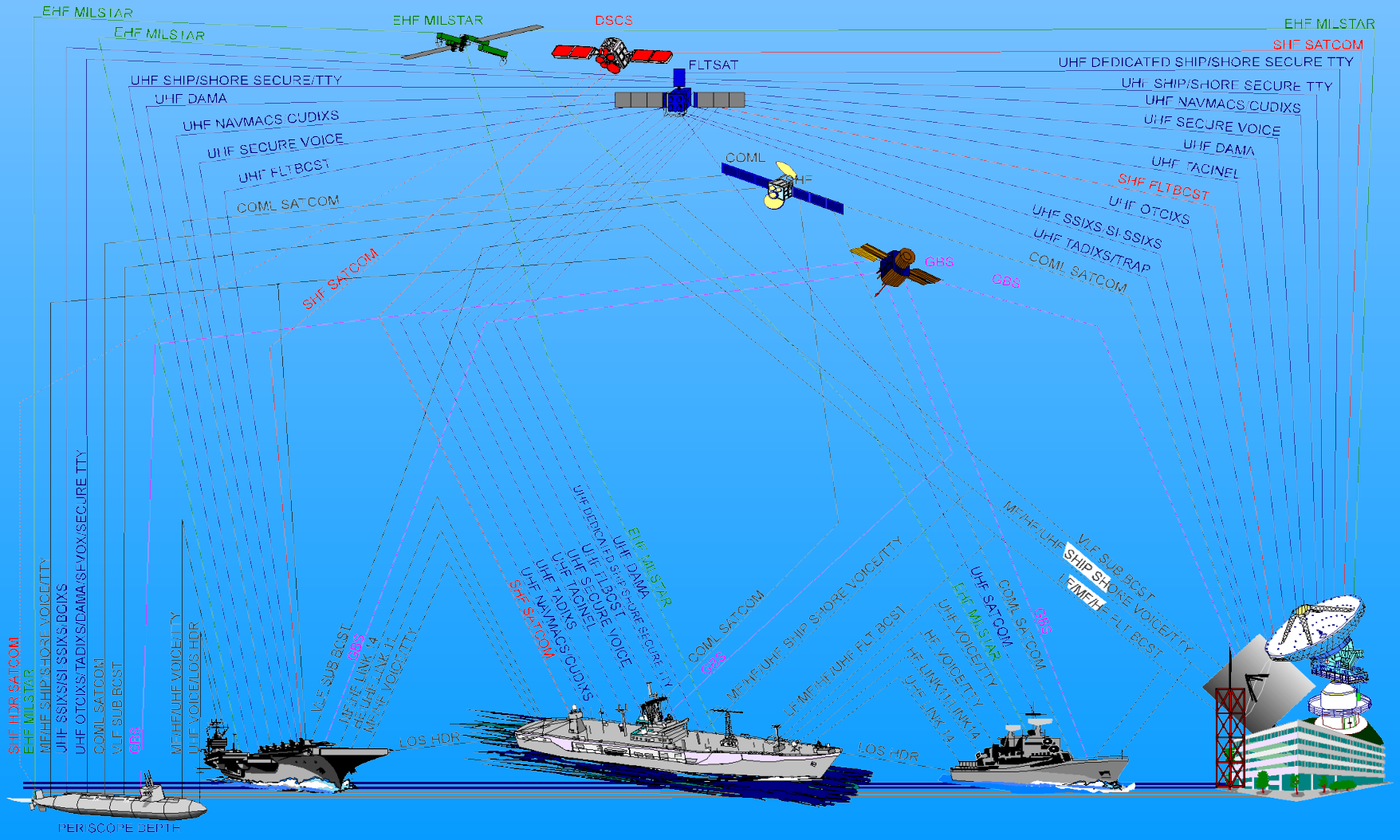

NETWARS Architecture

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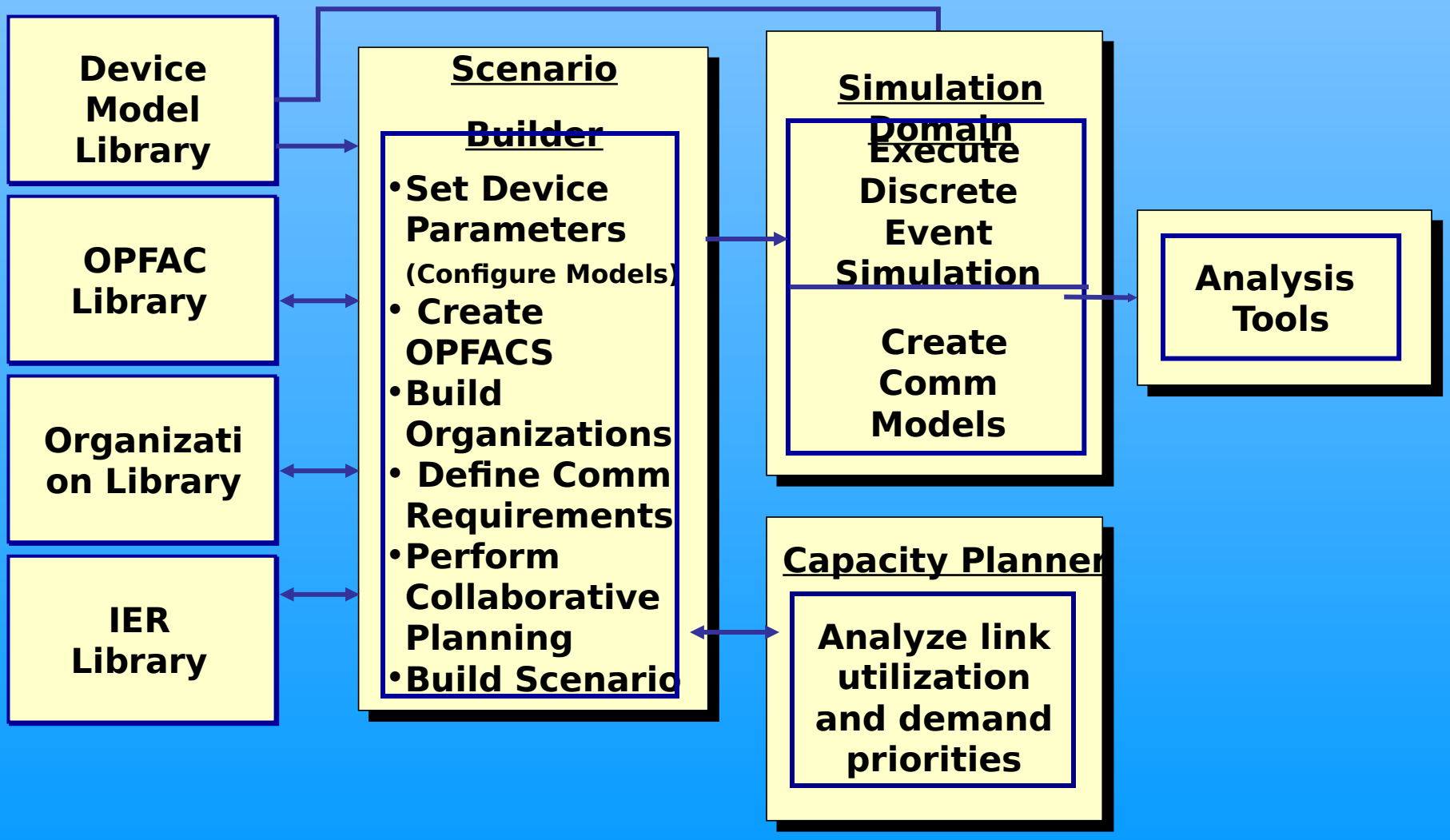

Hierarchical Model Development

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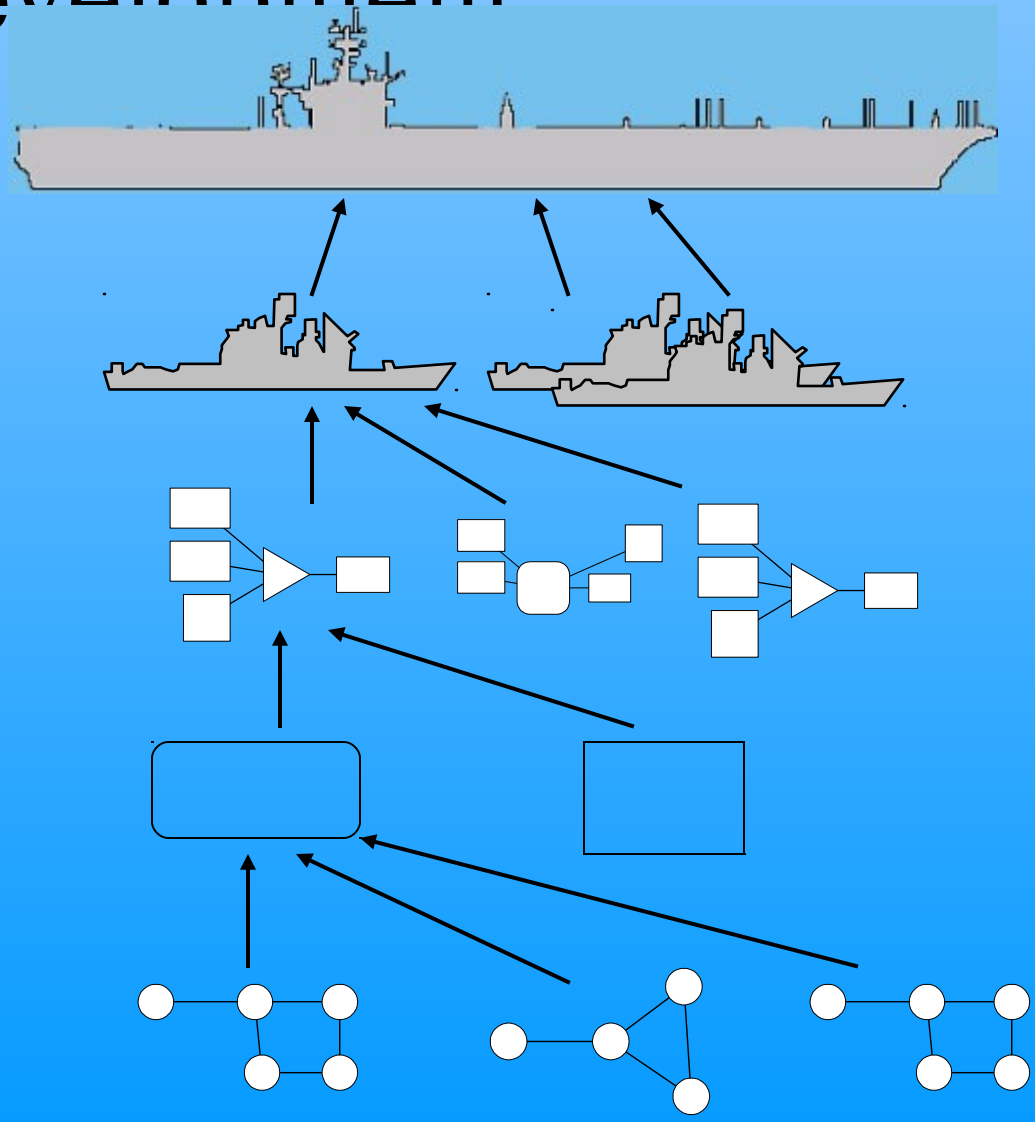
Deployment Models (e.g. STENNIS BG)

Organization Models (e.g. USS Lake Champlain)

OPFAC Models (e.g. ISNS)

Device Models (e.g. CISCO 7500 router)

Function and Process models (e.g. Ethernet)



NETWARS Models

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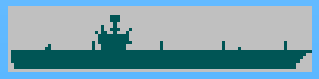
Systems and



- CVN
- LHD
- DDG
- CG

- TCA Ships
- ISNS U/C (various versions)
- JSIPS-N
- FLBCST

- ADNS
- EC5G LOE Lab
- FORCENET LOE Platforms
- GiG

- ADMS
- NCTAMS
- NNOC

Devices

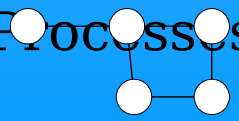
- Computers (Client/Server)
- Custom Workstations/Servers (PTW, IPL, etc).
- Routers (Cisco, Fore, etc.)
- Hubs (10baseT)
- Switches (100BaseT, 1000BaseT, etc.)
- Wired Links

- Link 11
- Link 16
- C2P
- EHF TIP
- Tactical Voice (KY68, STU-III, MMT, DNVT)
- Switched Voice (PBXs)
- TD1271 (DAMA)

- SATCOM Devices
- WSC 3/6/8 Radios
- USC 38
- TACINTEL
- IINMARSAT B Radio
- TACLANE
- KG 84/194

- Multiplexers (FCC100s, Timeplex Link 2/100s)
- Patch Panels
- BFEM Server
- Custom Workstations/Servers (PTW, IPL, etc).
- TCDL

Protocols and Processes



- Application Models (FTP, Rlogin, Email, etc)
- IP (v4, v6, & QoS)
- ATM
- AAL
- Token Ring

- Frame Relay
- Ethernet (10 Mbps, 100 Mbps, etc.)
- TCP
- UDP
- JRE (JREAP A)

- STANAG 5066
- DSRMA
- Dynamic TDMA
- MANET Protocols (AODV, OLSR, etc.)
- DAMA

- Routing Protocols (RIP, OSPF, BGP, etc.)
- 802.11
- Wireless Channels (propagation models)
- SATCOM orbits
- Mobility

Recent M&S Studies

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- Represent the Navy in many M&S architecture and requirements efforts.
  - Standards, VV&A, HPCMPO
- South West and North East Asia (SWA, NEA) amphibious readiness group (ARG) assessment for NETWARS QDR.
- NCTAMS FMX network congestion analysis
- EC5G LOE Scalability Study
- Wireless MANET Subnet Relay prototype modeling.
- Unified Worldwide Ship-to-Shore Navy Network
  - EIGRP and OSPF routing study

Highlighted Studies

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- Time Critical Strike (TCS)
  - Assessment of various C4ISR system families to support TCS.
- Battleforce Composite Networking (BCN)
  - Examined JDN data transfers through JPN networks using IP QoS.
- Deployable Autonomous Distributed System (DADS)
  - Prototype modeling effort for distributed sensor networks.
- End-to-end test bed for PMW 179
  - TTIC lab model construction to augment hardware simulations.
- FORCENet LOE
  - Integrated hardware and software simulation assessment.

Time Critical Strike (TCS) Study

SPAWAR Systems Center San Diego

- Lead analysts for the TCS and BFC2 MCPs
  - ASN (RDA) CHENG
- Objective was to assess alternate TCS threads through different C4ISR system families.
- End-to-end latency performance focus
  - Operational Metrics (Time-On-Target)
- Modeled systems/threads
  - Operational
    - JSOW, E2C, F/A 18, CVN, UAV
  - Technical Communications
    - ISNS, SATCOM, TCDL, Link 16, JSIPS-N

TCS Sample Study Results

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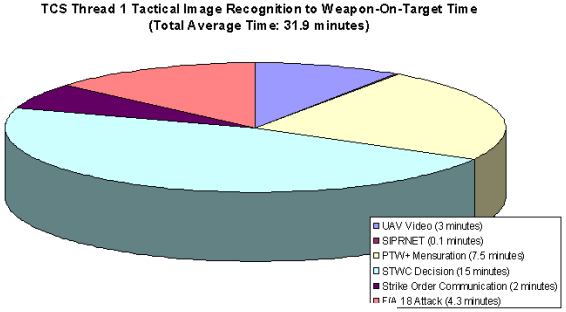
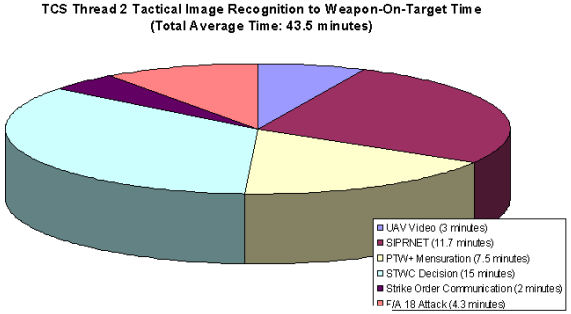
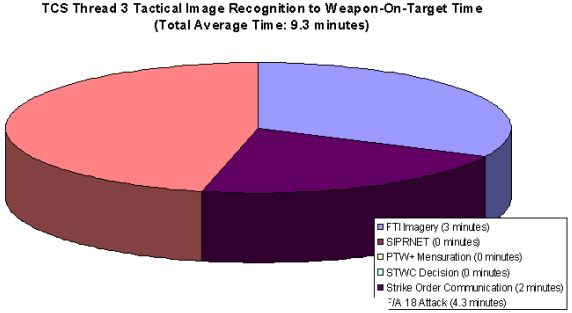

TCS Thread 1 Tactical Image Recognition to Weapon-On-Target Time
(Total Average Time: 31.9 minutes)
UAV Video (3 minutes)
SIPRNET (0.1 minutes)
PTW+ Mensuration (7.5 minutes)
STWC Decision (15 minutes)
Strike Order Communication (2 minutes)
F/A 18 Attack (4.3 minutes)

Thread # 1


TCS Thread 2 Tactical Image Recognition to Weapon-On-Target Time
(Total Average Time: 43.5 minutes)
UAV Video (3 minutes)
SIPRNET (11.7 minutes)
PTW+ Mensuration (7.5 minutes)
STWC Decision (15 minutes)
Strike Order Communication (2 minutes)
F/A 18 Attack (4.3 minutes)

Thread # 2


TCS Thread 3 Tactical Image Recognition to Weapon-On-Target Time
(Total Average Time: 9.3 minutes)
FTI Imagery (3 minutes)
SIPRNET (0 minutes)
PTW+ Mensuration (0 minutes)
STWC Decision (0 minutes)
Strike Order Communication (2 minutes)
F/A 18 Attack (4.3 minutes)

Thread # 3

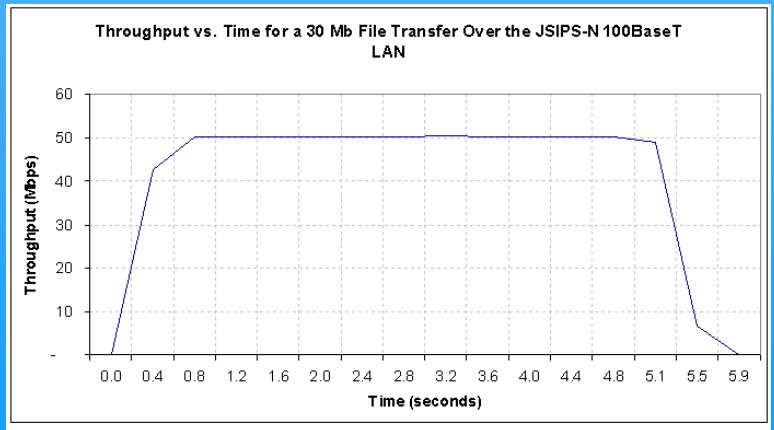


Figure 6-2. JSIPS-N LAN Throughput

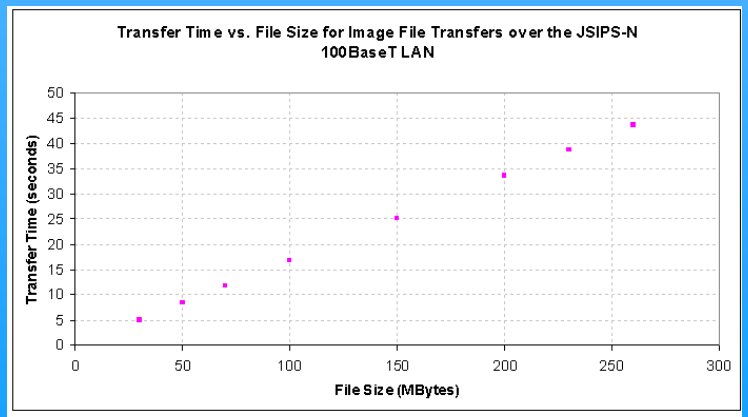


Figure 6-3. JSIPS-N Image File Transfer Time

Battleforce Composite Networking Study

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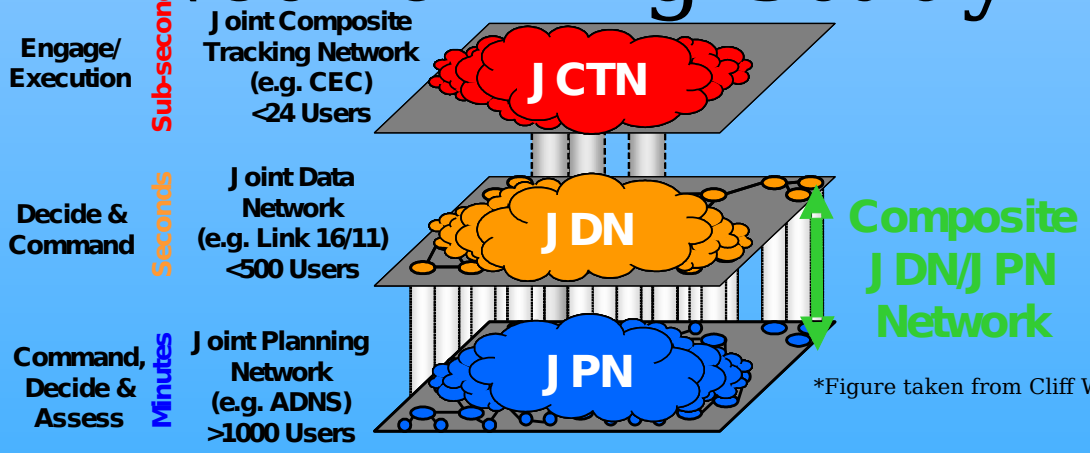

*Figure taken from Cliff Warner (SSCSD) BCN Briefs

- Integration of Tactical Data Links and ADNS using IP QoS technology and Composite Routing techniques
- Office of Naval Research (ONR)
  - Direction from SPAWAR PMW 159
- Modeled systems/protocols under this effort
  - IP QoS, C2P, JRE, Link 16, ADNS, EHF TIP
  - Other models reused from library.

Today's Architecture

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Background

Engagement

Common Tactical Picture

Common Operational Picture

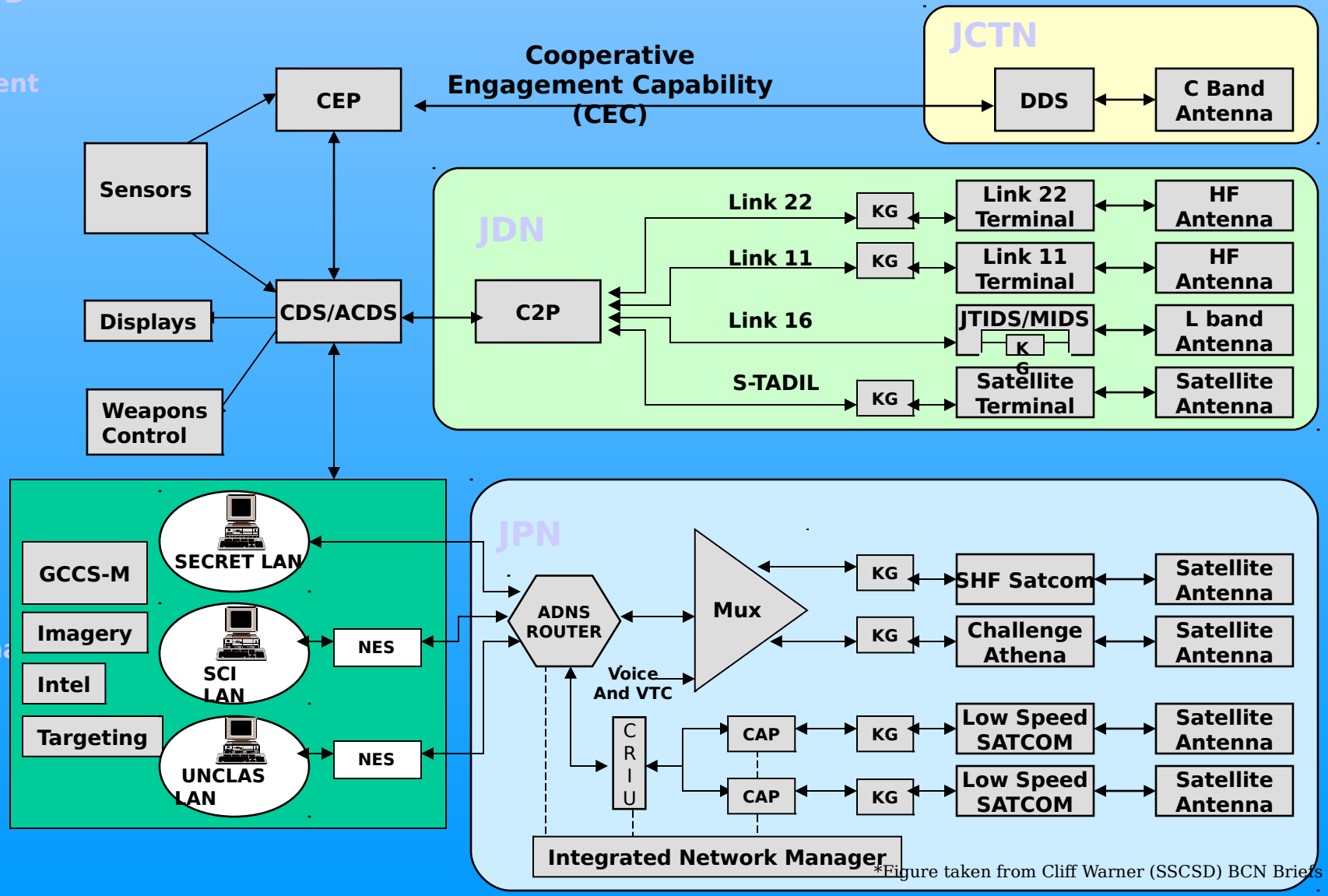

*Figure taken from Cliff Warner (SSCSD) BCN Briefs

BCN Architecture

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Technical Approach

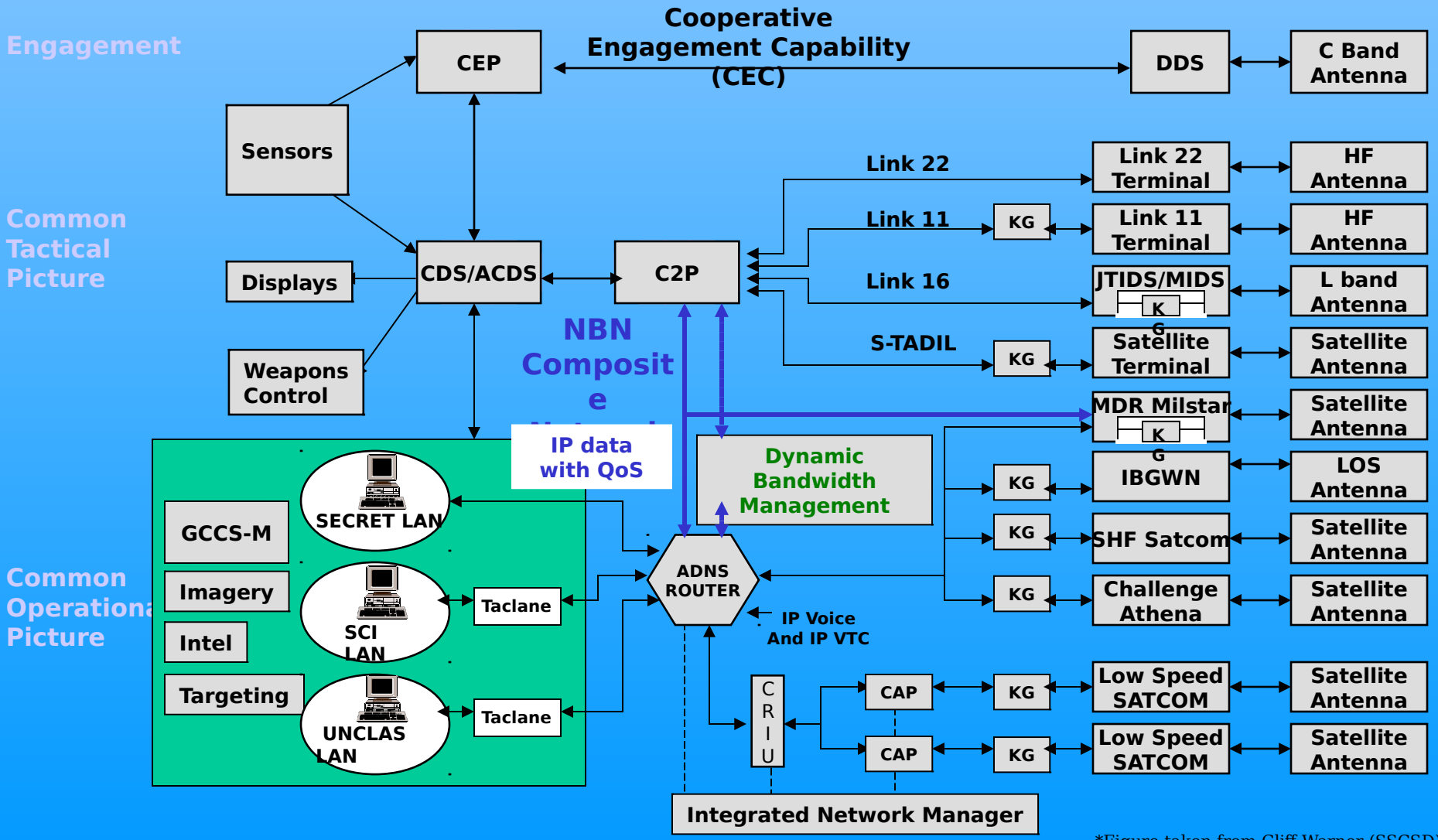

*Figure taken from Cliff Warner (SSCSD) BCN

BCN Sample Study Results

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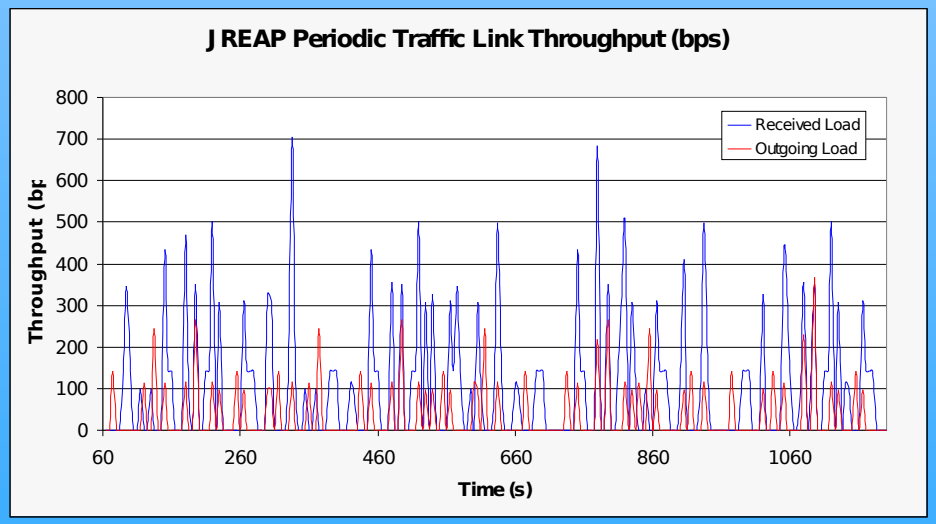

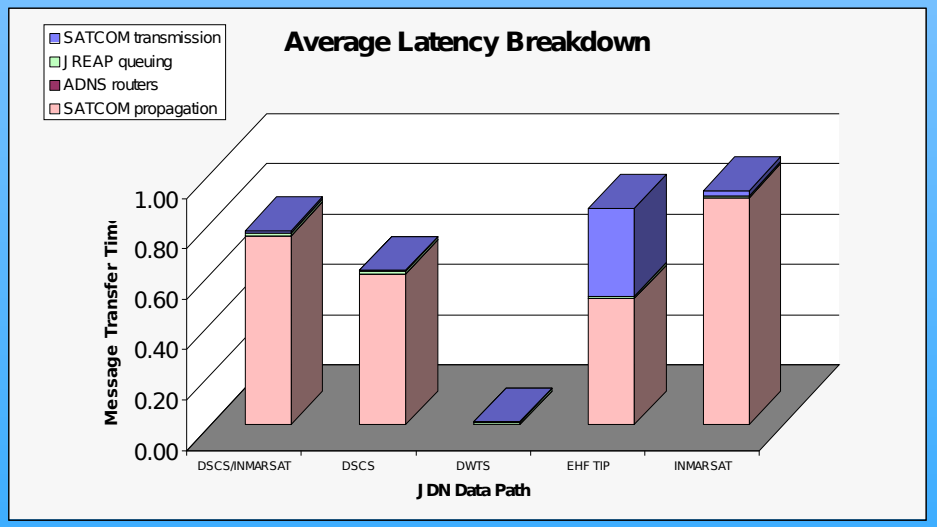

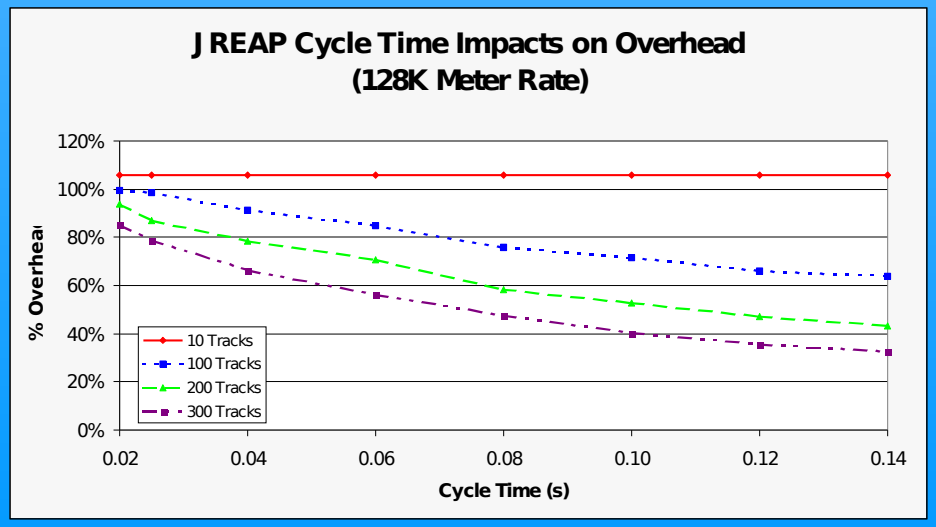

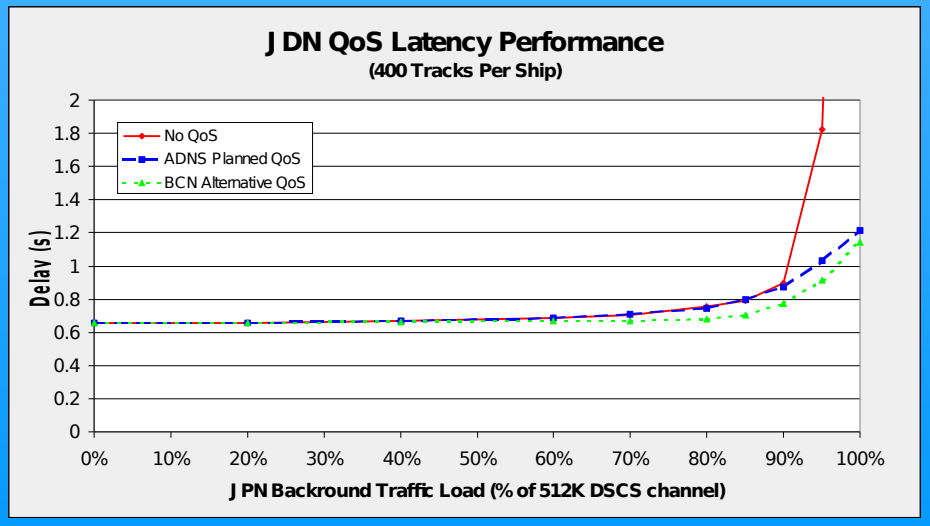

Deployable Autonomous Distributed System (DADS) Studies

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- Prototype development effort
  - Simulate first, then build
- Underwater acoustic sensor network
  - Coordinated sensor activity
  - Sensor-to-sensor communication
- Examine information latency/loss, coverage, and longevity of sensor networks.
  - Modeled initialization, maintenance, and reporting communications.
  - Modeled sensor and battery components.

DADS Sample Study Results

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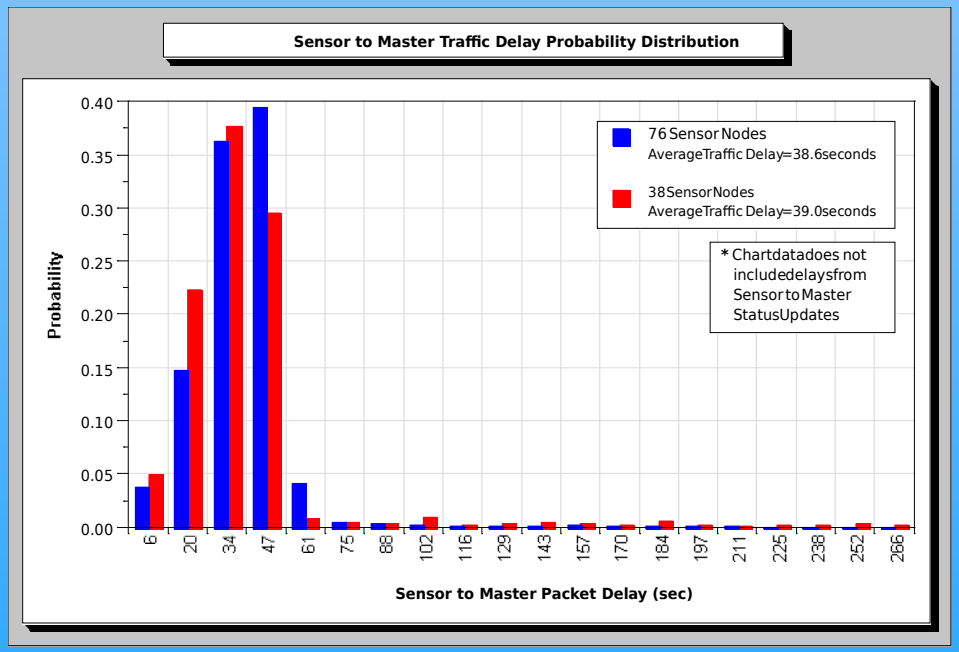

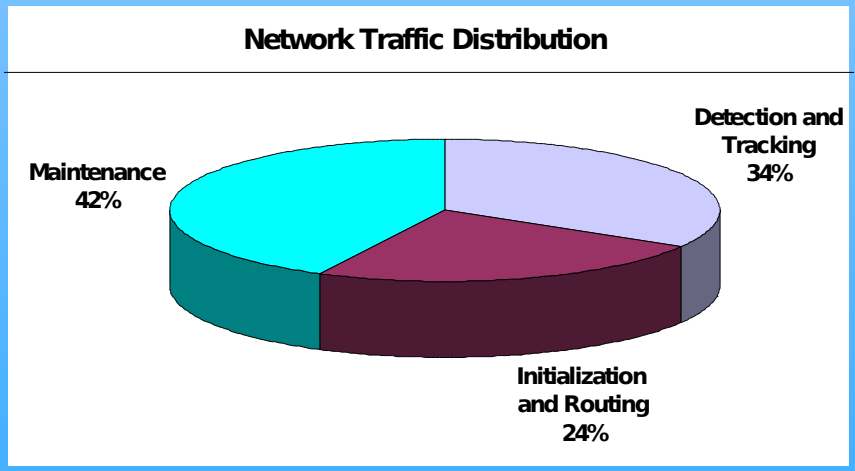

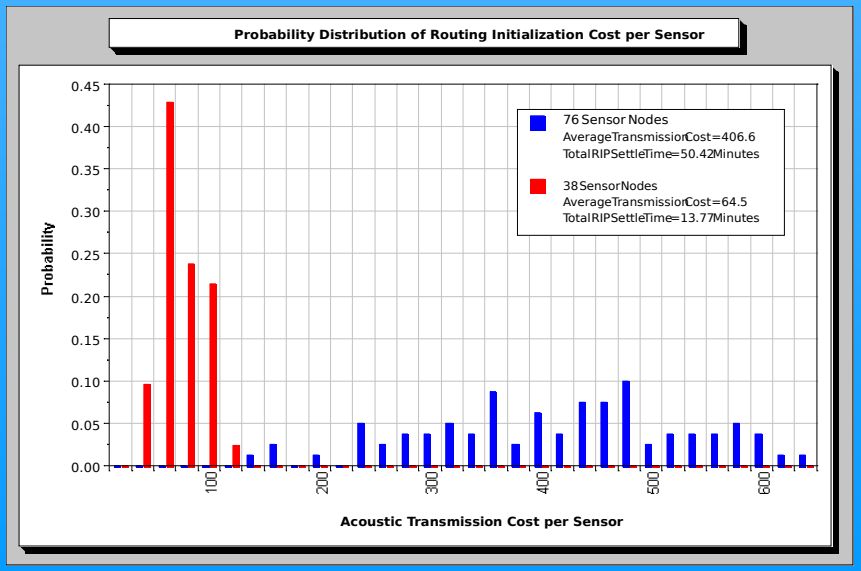

E2E Test Bed Model

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- Sponsored by SPAWAR PMW 179
- Objectives
  - Provide an End-to-End performance prediction capability.
    - Predict impact of new technology on end-to-end performance.
    - Extrapolate End-to-End performance through model scaling.
  - Develop NETWARS compliant models.
    - Reusable
    - Interoperable with NETWARS model library.

E2E Test Bed Approach

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- Develop a simulation model of the Transport, Test, and Integration Complex (TTIC) lab.
  - Validate simulation model against lab hardware.
- Augment TTIC studies by providing a cost-effective traffic and node scaling capability.
  - 100s of ships and shore facilities may be rapidly modeled.
  - TTIC study metrics are mirrored by the simulation model.
- Extend TTIC simulation environment.
  - SATCOM modeling using combinations of propagation models instead of SATSIM devices.
  - Low cost new technology modeling (equipment, prototypes).

E2E Test Bed TTIC Lab

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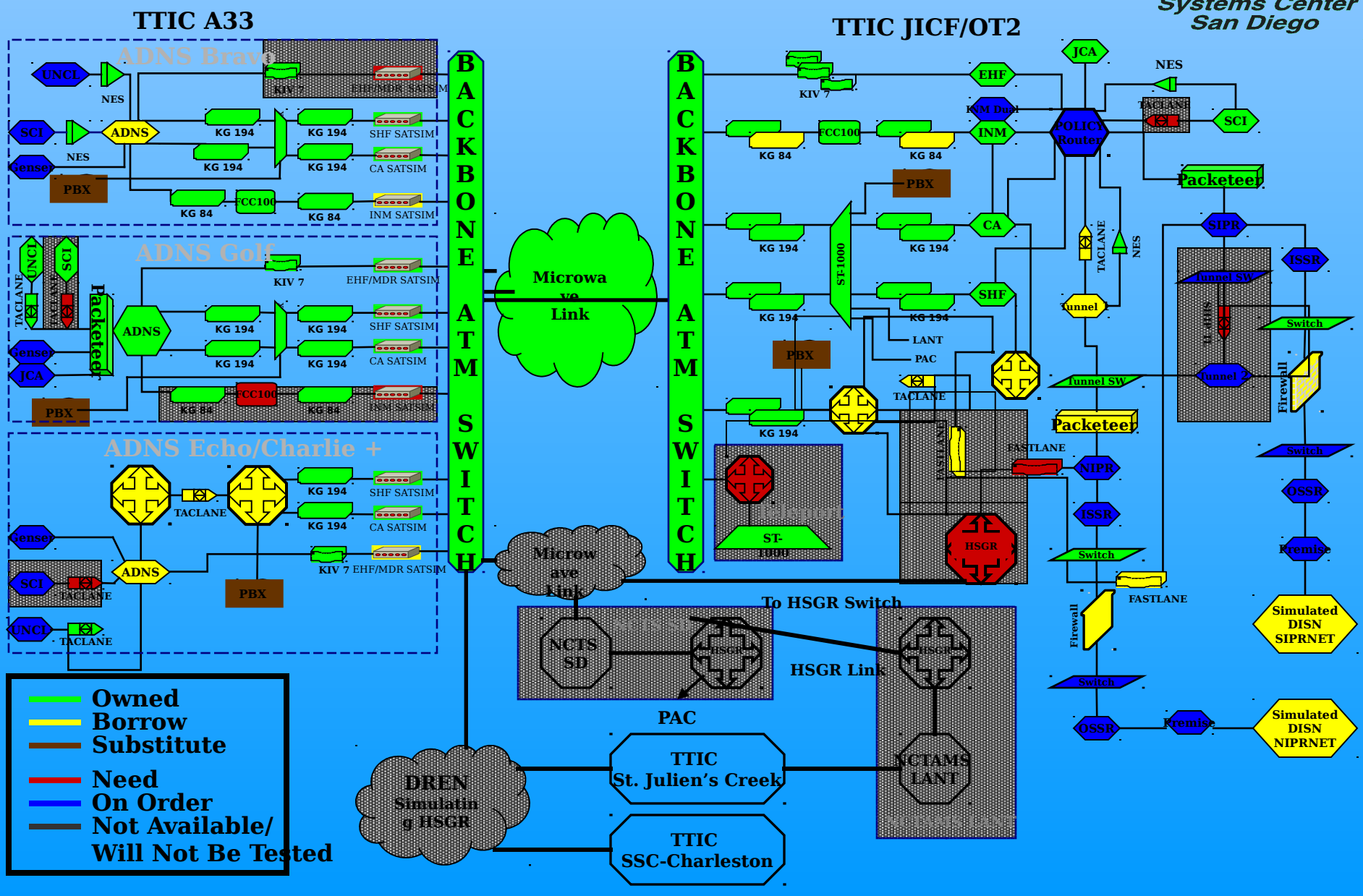

E2E Test Bed Network Model

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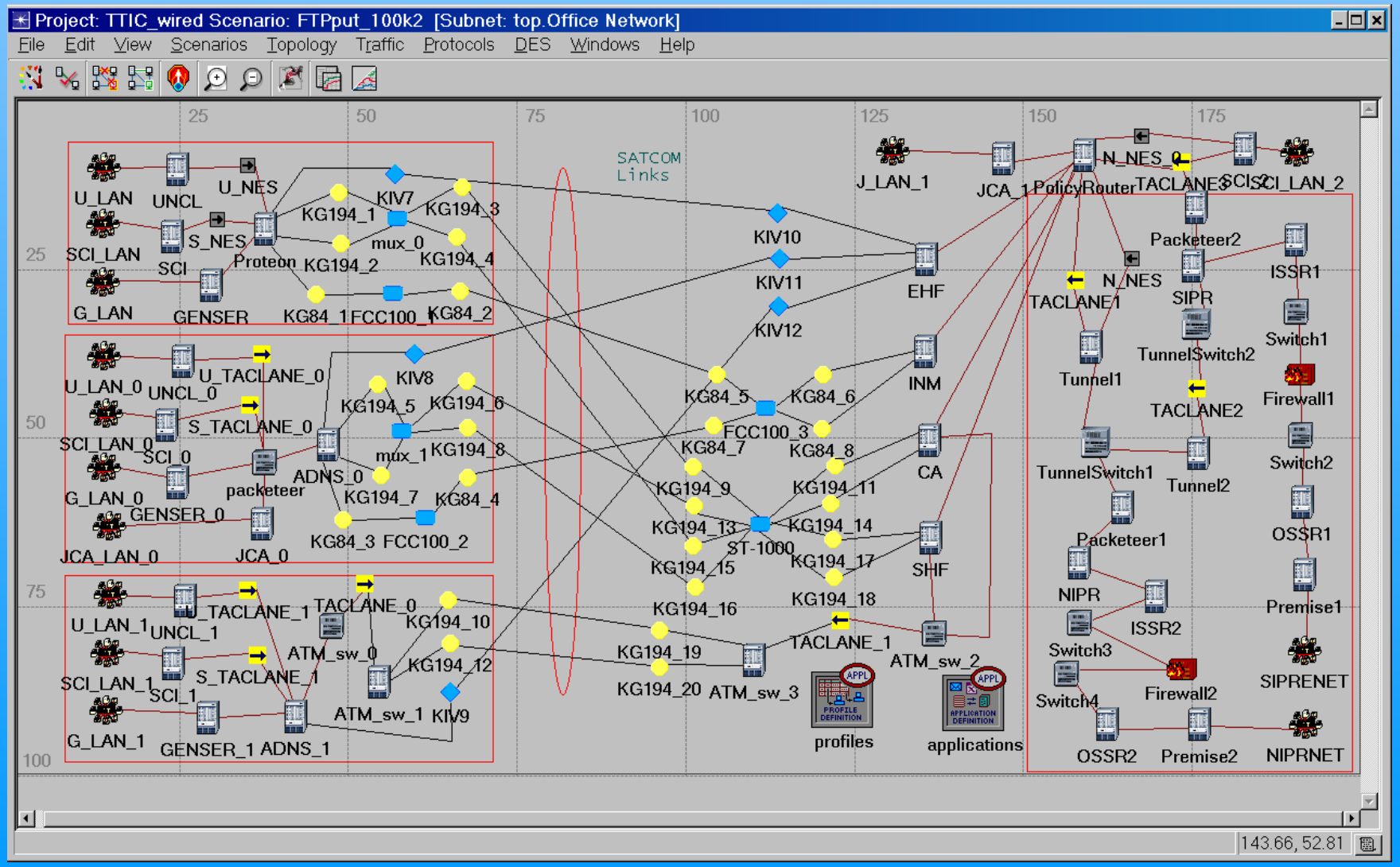

E2E Test Bed Status

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- Network model is under construction.
  - Topology matching.
  - Equipment configuration and settings (TCP, buffer sizes, etc.).
- Application models are under development.
  - Match TTIC Chariot application scripts in NETWARS.
- Matching of TTIC MOPs is underway.
  - Important for augmenting and scaling TTIC study efforts.
  - Derived from lab test plans and reports.

ForceNet Limited Objective Experiment (LOE)

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- Integrated hardware and software simulation assessment.
  - Emulated ships and Operational scenarios in labs.
- Objective was to assess benefits of ForceNet technologies.
  - IBGWN, ADNS Upgrades, CA SATCOM Upgrades, JTF WARNET, AFATDS, NFCS, GCCS-M, and ADOCS.
  - Collaborative Engineering Environment.
  - May 2003.
- Simulated Operational networks under four scenarios.
- Animation

NETWARS / NSS Federation

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NSS-NETWARS Integration Overview

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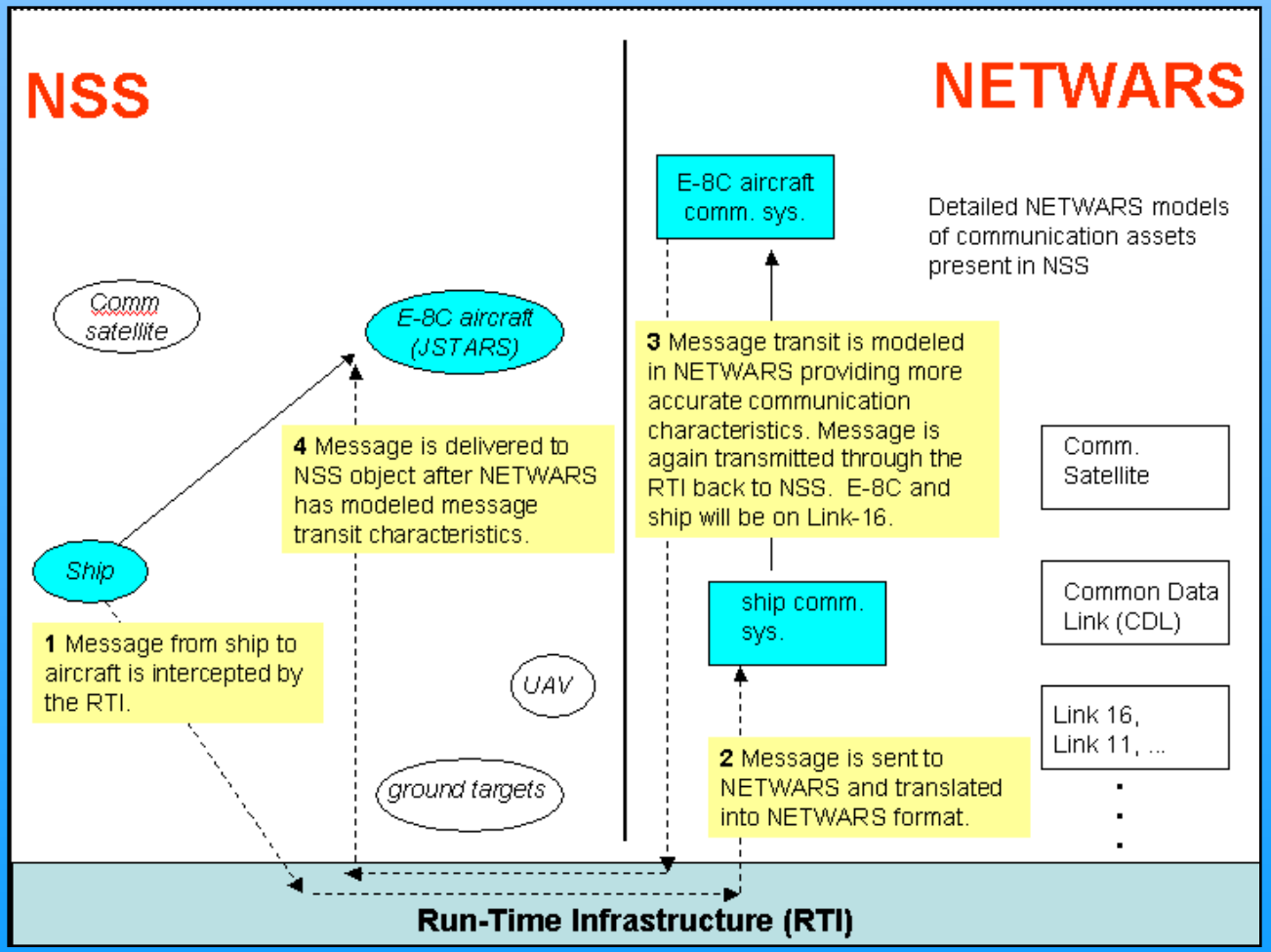
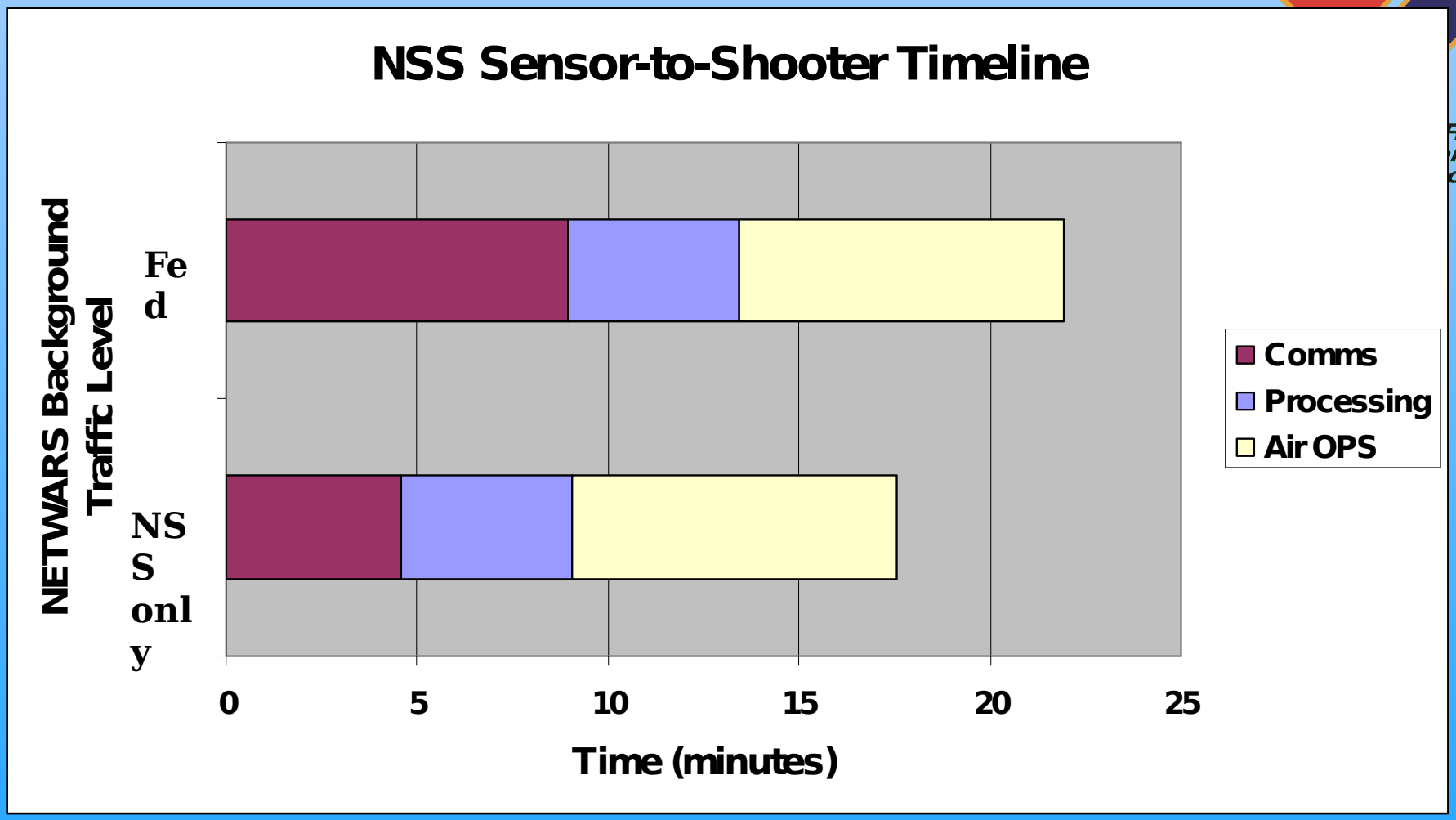

NSS
NETWARS
E-8C aircraft comm. sys.
Detailed NETWARS models of communication assets present in NSS
Comm satellite
E-8C aircraft (JSTARS)
3 Message transit is modeled in NETWARS providing more accurate communication characteristics. Message is again transmitted through the RTI back to NSS. E-8C and ship will be on Link-16.
4 Message is delivered to NSS object after NETWARS has modeled message transit characteristics.
Comm. Satellite
Ship
ship comm. sys.
Common Data Link (CDL)
1 Message from ship to aircraft is intercepted by the RTI.
UAV
Link 16, Link 11, ...
2 Message is sent to NETWARS and translated into NETWARS format.
ground targets
Run-Time Infrastructure (RTI)



Because the target is only detectable for certain intervals, increases in comms delays can have compounded effects on mission-level effectiveness:

- NSS simulation runs results in a 49% probability of attriting the target in the first hour, vs. 43% in in a federation run.
- Average time of first weapons launch is 1.36 hrs. in the NSS run simulation case, vs. 1.53 hrs. in the Federation simulation case.

Federation runs with channel errors

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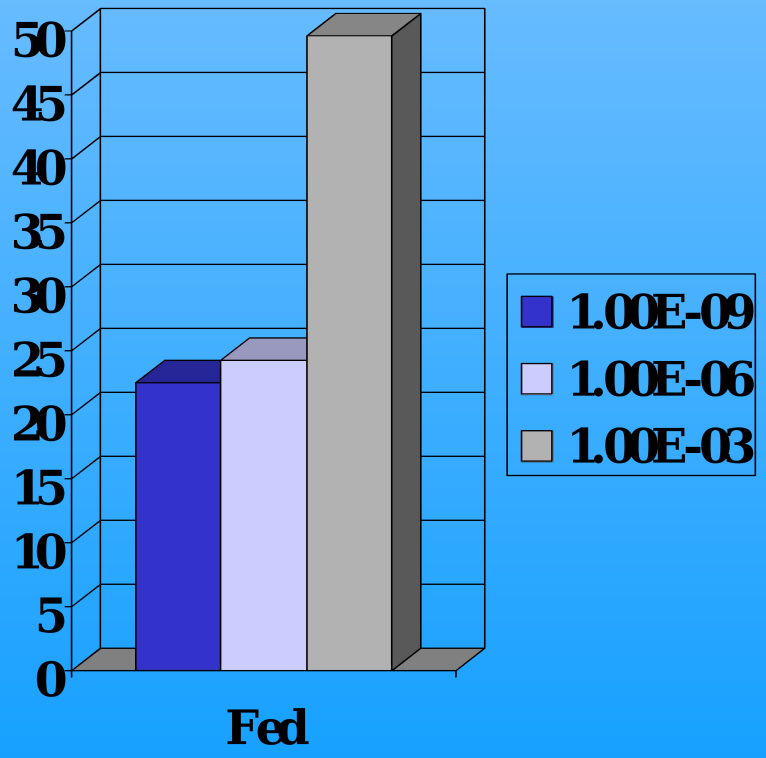
- Additional runs with channel bit errors
- Delays have impact to operational metrics



WCM-29

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Task 1: Develop XML Connection from NETWARS to NSS

Develop an XML tool to enable the automated transfer of network architectures, performance parameters and other characteristics from NETWARS to NSS. The purpose of this effort is to conduct computer network attack modeling within NETWARS to produce the performance parameters of a network based on the effects of Information Operations and then use this modified network parameters in NSS to measure the impact on the battlefield.

METRON will coordinate their efforts with SPAWAR and the Naval Postgraduate School (NPS) to ensure compliance with the DoN XML format. METRON will coordinate with SPAWAR in the development of the tool to enable the use of NTIRA to populate the NETWARS model with the identified network and its performance parameters.

Task 2: Conduct IO Modeling in MCO-2 Scenario

Conduct a Modeling and Simulation analysis of the impact of IO operations on a Maritime mission. METRON will use the MCO-2 2020 scenario - PACCOM MCO-2 & MCO-3 2020 Network Centric Warfare. METRON will use the scenario to measure the impact of IO versus the original baseline.

NSS Improved TCP/IP Modeling for PR-07 ETWARS Outputs

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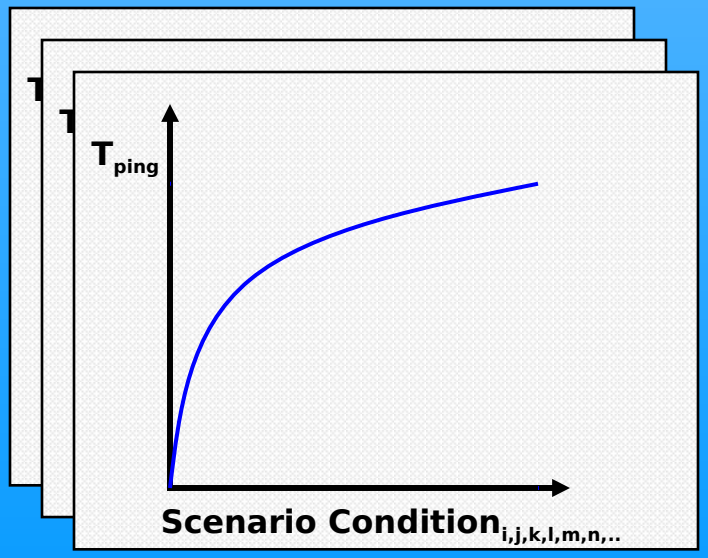
- Sets of T_{ping} values, where:
  - $T_{ping}(Source_i, Destination_j, Utilization_k, IO\_Attack_l, Priority_m, Connection_n, \ldots)$ is the network latency between Source *i* and Destination *j* under a network utilization level of *k*, during an IO Attack *l*, with a message priority level of *m*, a selected TCP/UDP connection of *n*, etc.



Serial Simulation Concerns

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- Serial input is mathematically incorrect
  - Loss of correlation
  - Loss of interaction
  - Simple Proof
    - Let Sim_1 generate $\underline{X}(\varepsilon,t)$
    - Let Sim_2 generate $\underline{Y}(\varepsilon,t)$
    - Overall study goal is to compute the $E[\underline{Y}(\underline{X}(t)]$
    - $Y(E[\underline{X}(t)]$ is generate from serial simulation runs
    - Hence, in general, **$E[\underline{Y}(\underline{X}(t)] = \underline{Y}(E[\underline{X}(t)]$**
- Run-Time concerns from running selected deviations $\underline{X}(\varepsilon,t)$

Lessons Learn

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- Accuracy
- Lookahead
- Model Fidelity
- IER Structure
- **Process Model *oe_iers.pr.m***
  Process Model *oe_status.pr.m*
- **External Code File *netwars_support.ex.c***

Summary

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- Simulation-based Acquisition
- Federation support leverage a tool's strengths, to promote reusability and interoperability.
  - integration of NETWARS and NSS is an endeavor in this direction.
  - Based on this effort, studies are being conducted to provide the acquisition managers with improved communications analysis methods that will ultimately provide the warfighter with improved communication capacity. … Hence Network Centric Operational Analysis